KATHOLIEKE
UNIVERSITEIT
LEUVEN

DEPARTEMENT TOEGEPASTE ECONOMISCHE WETENSCHAPPEN

RESEARCH REPORT 0004

**EXTERNAL TECHNOLOGY SOURCES:
EMBODIED OR DISEMBODIED TECHNOLOGY
ACQUISITION**

by
B. CASSIMAN
R. VEUGELERS

D/2000/2376/04

External Technology Sources: Embodied or Disembodied Technology Acquisition [*]

by

BRUNO CASSIMAN
Universitat Pompeu Fabra
Ramon Trias Fargas 25-27
08005 Barcelona, Spain
Email: cassiman@upf.es
Tel: 34-93-542 27 23
Fax: 34-93-542 17 46

and

REINHILDE VEUGELERS
Katholieke Universiteit Leuven and CEPR
Naamsestraat 69
3000 Leuven, Belgium
Email: Reinhilde.Veugelers@econ.kuleuven.ac.be
Tel: 32-16-32 69 08
Fax: 32-16-32 67 32

January 2000

[*] Comments from participants in the SESSI conference on "Innovation, appropriation strategies and economic policy", Paris and more particularly from B. Van Pottelsberghe are gratefully acknowledged. The first author acknowledges support from DGES PB96-0302 and CIRIT 1997SGR00138, the second author from CNRS, Enjeux Economiques de l'Innovation and NFWO (G.0131.98).

Abstract

This paper analyzes the choice between different innovation activities of a firm. In particular, we study the technology acquisition decision of the firm, i.e. its technology BUY decision as part of the firm's innovation strategy. We take a closer look at the different types of external technology acquisition where we distinguish two broad types of technology buy decisions. On the one hand, the firm can acquire new technology which is *embodied* in an asset that is acquired such as new personnel or (parts of) other firms or equipment. On the other hand, the firm can obtain new technology *disembodied* through a licensing agreement or by outsourcing the technology development from an R&D contractor or consulting agency. Through a series of Probit regressions, we discuss variables that might affect external technology acquisition choices of the firm and pay special attention to the firm's abilities to scan the market for technology and to absorb the technology acquired. Furthermore, we analyze the effect of different appropriation regimes on the decision of the firm to source technology.

Keywords: Technology acquisition, innovation, appropriability, absorptive capacity.
JEL: L22, O32

1. Introduction

Successful innovation depends on the development and integration of new knowledge in the innovation process. Today even the largest and most technologically self-sufficient organizations require knowledge from beyond their boundaries. In order to access alternative knowledge sources, the innovation strategy of the firm will combine different innovation activities. In addition to doing own research and development, firms typically are engaged in the acquisition and sale of knowledge on the technology market and cooperate actively in R&D with other firms and research organizations. Furthermore, they can attempt to absorb existing technology without any explicit involvement or permission from the innovator. However, external knowledge sources and spillovers do not automatically find their way into the firm's innovation process. An important task in innovation management, therefore, is to optimally integrate external knowledge into the firm's innovation process.

While there is ample theoretical and empirical research on firm and industry determinants of internal R&D, the literature deals less with the choice between different innovation activities, in particular external technology acquisition. In this paper we study the technology acquisition decision of the firm, i.e. its technology BUY decision as part of the firm's innovation strategy. First, we discuss the variables that might affect the decision of the firm to buy technology. Second, we take a closer look at the different types of external technology acquisition. We distinguish two broad types of technology buy decisions of the firm. On the one hand, the firm can acquire new technology which is embodied in an asset that is acquired such as new personnel or (parts of) other firms or equipment. On the other hand, the firm can obtain new technology disembodied through a licensing agreement or by outsourcing the technology development from an R&D contractor or consulting agency.

The performance of a firm's innovation strategy that relies on successfully integrating externally acquired technology, depends not only on a successful outcome of the innovation process based on this information, but also on the ability of the firm to appropriate the benefits from this innovation. The success of the innovation process depends on the internal research capabilities of the organization. With respect to externally acquired technology these capabilities perform two functions. First, the research capability of the organization allows the firm to better scan the environment for relevant external technology sources. Second, the internal research capability of the firm increases its absorptive capacity and improves the integration of external knowledge into the innovation process. In our analysis we will attempt to identify both of these effects of own research and development.

Futhermore, the appropriability regime will affect the decision to buy technology externally, as well as the mode in which the acquisition will occur. In general, we would expect that better appropriation of innovation results would lead to more technology transactions. Better legal protection might favor disembodied technology transactions, while strategic protection, which is based on co-specializing assets, would lead to more embodied technology transactions. If the firm's competitive advantage is based on gaining lead time on competitors, we might also observe more firms buying technology, which typically saves time compared to own development.

Using data from the Community Innovation Survey on Belgian manufacturing firms, our empirical results indicate that the capability to scan the external environment for new technology is important in understanding the decision of the firm to buy technology. The capability of the firm to integrate new external knowledge into its innovation process, however, is only significant for the disembodied technology acquisition, and more specifically for the R&D contracting. Appropriability through legal mechanisms positively affects disembodied technology acquisition, in particular licensing. Strategic protection, on the contrary, strongly determines the embodied technology acquisition mode. Other variables of interest are risk and costs of the innovation process, and lack of innovation personnel. Higher levels of uncertainty of the innovation process reduces the likelihood that firms are able to agree on the transfer of disembodied technology and the lack of innovation personnel increases the likelihood of buying technology in the form of R&D contracting. High costs for developing technology drive firms to buy existing embodied technology.

The next section reviews the literature on technology buy decisions. Section 3 describes our sample and section 4 presents the results on who buys technology and how they organize these transactions. Section 5 concludes.

2. Technology Buy: Theory

The existing literature on the decision to buy technologies is mostly focused on the "make versus buy" decision. Less theory exists on comparing different modes of trading technology. This section reviews the economic theory on technology buy, scans the technology management literature on advantages and disadvantages of the various modes of technology acquisition, to conclude with related empirical studies.

In the **economics literature**, technology acquisition is typically of the disembodied kind, through *R&D contracting*. Building further on the general literature on make or buy decisions, i.e. transaction cost economics (Williamson, 1985) and property rights theory (Grossman & Hart, 1986), the theoretical framework to explain R&D outsourcing stresses the advantage of tapping existing often more specialized knowledge if available. This leads to time gains and lower innovation costs to the extent that economies of scale in R&D can be more efficiently exploited. However technology outsourcing may create considerable transaction costs, ex ante in terms of search and negotiation costs and ex post to execute and enforce the contract. The typical uncertain nature of R&D projects exacerbates these transaction costs. Hence, R&D contracting is more likely to occur for generic, non-firm specific R&D that allows for specialization advantages, such as routine research tasks like materials testing, and process rather than product innovations (Mowery & Rosenberg, 1989).

The economic literature on buying technology disembodied through *licensing* usually takes the position of the seller, analysing the motives for licensing one's technology, rather than to focus on the decision of the licensee to buy or not. These licensing motives range from generating a stream of licensing revenues over increasing own sales to strategic motives, preempting the emergence of strong competitors who would else develop own technology (Gallini (1984) Katz & Shapiro (1986)).

In addition, the appropriability regime will influence the innovation strategy selected (Teece, 1986). When appropriability is high, firms are willing to develop technology internally and to sell their technology to other firms to appropriate the benefits from innovating. Hence, firms that decide to acquire technology externally, are more likely to acquire this technology in disembodied form such as through licensing agreements or R&D contracts. Loose appropriation environments quickly erode a firm's technological advantage. In that case firms will develop specialized complementary assets internally to protect their technology. This is reminiscent of the "resource based" view of the firm who stresses the imperfect mobility of resources as a condition to sustain a firm's competitive advantage. Firms that decide to acquire technology externally, acquire this technology in embodied form through the acquisition of other firms or by attracting specialized personnel. Furthermore, we expect external technology sourcing when assets complementary to the technology are in competitive supply such that the small numbers bargaining hazards are minimized (Pisano, 1990).

The difficulties in appropriating know-how allow for knowledge to diffuse, and external know-how to be accessed, without any explicit involvement from the sending party and even despite attempts from firms generating know-how to keep this proprietary (Arrow (1962)). The channels through which such "spillovers" occur are many. Next to information leakage channels such as informal communications networks, meetings, input suppliers and customers, patent applications, Mansfield (1985) identified mobility of researchers and reverse engineering as important channels through which such "spillovers" occur. While the former are spillovers in the sense that there is no "direct purchase" from the original source, the latter two channels are embodied acquisition of know-how. By now an extensive theoretical literature in Industrial Organisation has developed around the effects of such spillovers on the incentives for investment in R&D (see De Bondt (1996) for a review). On the one hand, this literature demonstrates that spillovers reduce own R&D by the sending firm, since the latter cannot fully internalize all benefits from its investment, cf. the disincentive effect (Spence (1984)). Simultaneously, external R&D will typically substitute for own R&D in the receiving firm. This implies that own R&D and external knowledge received through spillovers act as substitutes. On the other hand, there is typically a market enhancement or cost reducing effect that should stimulate efforts. The size of these effects typically depend on the degree of competition between firms and the tightness of the appropriation regime (De Bondt et. al. (1992)). Related, the notion of 'absorptive capacity' introduced by Cohen & Levinthal (1989) stresses the importance of a stock of prior knowledge to effectively absorb spillovers. In such a setting, the desire to assimilate external know-how creates a positive incentive to invest in R&D. Hence spillovers may rather than diminish own R&D encourage equilibrium industry R&D investments.

The **technology management literature** emphasizes as advantages of external sourcing the option to get quick access to technological know-how, which is important when the firm lacks familiarity with, or competence in, the new market/technology. At the same time this already indicates a major roadblock to external sourcing, namely matching the existing technological capabilities of the receiving firm with the transmission capacity of the source. Chatterji (1996) pinpoints as a general problem in external sourcing strategies an insufficient "post-agreement" management and commitment to the external sourcing strategy. To overcome the extra costs of external sourcing, an organisational structure that builds in absorptive capacity and is able to overcome the classic "not invented here" syndrome, is an important asset. Allen (1986) suggests the use of technological gatekeepers to improve the external sourcing strategy, as a way of bridging the gap between internal and external environment.

Next to organisational issues, the effectiveness of transfer is also determined by the nature of the innovation. Transfer is easier when the know-how is less complex, less radical and less tacit (Afuah (1998)). This relates to the life-cycle of the technology. Utterback & Abernathy (1975) already stressed that external sourcing is less likely to occur for technologies that are still in their initial development stage, when there is lots of uncertainty surrounding the technology.

The technology management literature also discusses the different modes of accessing external sourcing (Chatterji (1996)). When choosing the mode of external sourcing, ranging from acquisition to majority-minority holdings to networking and short-term contracting, the basic trade-off is commitment and control versus flexibility. [1] More flexible modes are more attractive for ill-defined, embryonic technology with a high level of risk for which the company is unfamiliar, while higher control modes are more important when appropriation is weak, assets specialized and the technology is highly relevant for sustaining a competitive advantage.

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[1] A seminal paper is Roberts & Berry (1985) that stresses the importance of the level of familiarity with the market and technology when choosing the mode of new business development. Acquisitions or licensing are preferred when the changes are small to modest, while for radical innovations Roberts and Berry suggest using more flexible modes such as venture capital. A similar trade-off prevails in a more broader literature on the mode of technological cooperation (Cheesa & Manzini (1998), Chesbrough & Teece (1996), Oxley (1997)

Given the scarcity of adequate data, the choice of external sourcing mode remains relatively unexplored in **empirical studies**. Pisano (1990) uses data from biotech projects from pharmaceutical companies to study the choice between internal and external sourcing. After controlling for size, nationality and expercience, he finds support for the small number hazard problem pushing towards internal sourcing. Similarly, Grandstand & Sjölander (1990) using case studies and pilot surveys to study acquisition of new technology-bases firms (NTBFs) by large firms, find that when the innovation is characterized by a seller's market, acquisitions of NTBFs are less successful. In addition, they report continuity of key R&D personnel and top management as important for success. Arora & Gambardella (1990) study four types of external sourcing strategies for large chemical and pharmaceutical companies in biotechnology (agreements with other firms, with universities, investments in NTBFs and acquisitions of NTBFs). They find evidence for complementarity for all types of sourcing strategies, even after correcting for a set of firm characteristics. The correction for firm characteristics suggests that large firms with higher internal knowledge, measured by number of patents are more actively involved in pursuing strategies of external linkages.

The complementarity between internal and external sourcing is further explored in Arora & Gambardella (1994), where they identify two effects from internal know-how. On the one hand, internal know-how is necessary to screen available projects. On the other hand, internal know-how serves to effectively utilize the external assessed know-how. Using scientific know-how as proxy for the first role, and technological know-how for the second, they find support for both. Blonigen & Taylor (1997) also identify two possible hypotheses for the effects of R&D activities of the firm on its acquisition strategy. The first hypothesis states that internal R&D and technological acquisitions are substitutes leading to a negative relationship between the two, while the second hypothesis argues that internal R&D stimulates synergy gains from potential targets, and therefore leads to a positive relationship between the two. Using R&D intensity to test for the first hypothesis, and R&D expenditures to test for the latter, they find support for both hypotheses on a panel of US electronics firms. Also Veugelers & Cassiman (1999) find evidence for internal know-how development and external sourcing to complement each other at the firm level, while Veugelers (1997) finds external sourcing to stimulate internal R&D expenditures, at least for firms with internal R&D departments.

3. Sample

The data used for this research are innovation data on the Belgian manufacturing industry that were collected as part of the Community Innovation Survey conducted by Eurostat in the different member countries in 1993. A representative sample of 1335 Belgian manufacturing firms was selected resulting in a response of 735 usable questionnaires. [2] About 60% of the firms in the sample claim to innovate, while only 40% do not innovate. We restrict the analysis to the 494 innovative firms in the sample. These firms introduced new or improved products or processes in the last two years and returned a positive amount spent on innovation.

For this sample we can identify whether and how firms acquire new technology. Identification of external sourcing is based only on whether one of these external sourcing activities have been used or not. Information on budgets was incomplete and unreliable. We classify technology acquisition in two broad categories. First, the organization can acquire new technology that has to be assimilated by the organization. **Disembodied** technology acquisition strategies include licensing, R&D contracting and the use of technology consulting agencies. Second, new technology can be acquired that is embodied in the good or asset that is acquired: **embodied** technology acquisition. Such strategies include acquisition of firms (take-overs) and attracting qualified personnel. The "embodied" purchase of equipment, is reported as well but not included in the main analysis. This is because too many firms responded positively on this item. Probably not all of them interpreted the question as buying equipment with the explicit purpose of obtaining new technologies as an alternative to developing the technology internally. [3] Also reported separately is the category of "other forms of acquisition". Although this could be capturing involuntary spillovers, it is not retained in the main analysis as a buying activity since it is unclear what is included here.

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[2] The researchers in charge of collecting the data also performed a limited non-response analysis and concluded that no systematic bias could be detected (Debackere & Fleurent, 1995).

[3] In addition, buying equipment from suppliers, is clearly a different strategy, as noted by Pavitt (1984), who found that supplier dominated industries are less R&D intense and more process oriented than other industries.

Insert Table 1 about here

Table 1 shows that of all innovation-active companies in the sample, 331 or 67%, were identified as acquiring technology in disembodied or embodied form. If we would have included purchase of equipment this would have resulted in 80% of innovative companies buying technology externally. Of those who buy technology, 86% also do R&D internally, i.e. combine make and buy, while 60% of technology buying companies also cooperate on R&D. All this seems to suggest that acquisition of external know-how is embedded within the acquiring firm's larger innovation strategy.

The data are most unique in their ability to disaggregate the acquisition of technology into its various modes. About 77% of companies buying technology do this disembodied, ie through (in decreasing order:) R&D outsourcing, licensing and consulting. Ignoring the purchase of equipment, the mechanism used most frequently for acquiring technology, is hiring skilled people (58%). Important to note is that firms often combine embodied and disembodied acquisition of technology: 43% of all technology buying companies use both embodied and disembodied purchase. In addition, firms that have own permanent R&D activities are more likely to be engaged in R&D contracting, indicating a strong complementarity between own R&D and this mode of external technology sourcing[4]

Insert Table 2 about here

In the sample of innovative companies, 31% have less than 50 employees. If we restrict the sample to these small firms (see Table 2), the percentage of innovative small firms that are buying drops to 50%. Small firms are especially less likely to buy disembodied technology: R&D contracting, R&D consulting and licensing. For example, only 12% of firms contracting out R&D have less than 50 employees,

[4] 53% of permanently R&D active firms use R&D contracting, while this is for 46.5% for the total sample, a difference that is statistically significant. This is the only mode for which a significant difference is detected between permanent R&D active and non-active firms.

indicating a significant underrepresentation. For the embodied technology acquisition in the form of hiring of personnel, the share of small companies is 26%, again a significant underrepresentation.

Besides characterizing the innovation strategies of the companies along the buy dimension, the questionnaire also allows us to assess other important dimensions of the innovation process. The respondents were asked to rate the importance to their innovation strategy of different information sources for the innovation process, the effectiveness of protection of innovations and the importance of different obstacles to innovation. [5]

4. Econometric results on who buys and how they buy?

To analyze the different ways that firms can structure their external technology acquisition activities, we classify all the actively innovating firms according to the various embodied and disembodied technology acquisition modes. We first analyse the firm and industry variables determining the decision to buy technology in general. The same set of firm and industry variables is then used to analyse each technology acquisition mode separately. This allows us to compare the importance of different characteristics according to the different modes. There exists very little theory to formulate hypotheses on the variables that influence the decision of the firm to opt for different modes of technology acquisition and in particular whether this acquisition happens in embodied or disembodied form. The results reported here should therefore be considered indicative of important relations between the mode of technology acquisition and firm and industry characteristics, and, are intended to stimulate further research on the issue.

4.1 The variables and hypotheses

As firm characteristics we include SIZE, as measured by sales. Larger firms may have higher market power or they may enjoy economies of scale which raise the payoffs to all or some external sourcing strategies. In addition, the data allow us to

[5] Firms had to rate their answer on a 5-point Likert scale (from unimportant (1) to crucial (5)). In order to manage the answers on these many questions, we aggregated the answers by summing the scores on related variables and rescaled the total scores to a

test whether obstacles to innovations such as uncertainty, lack of funds and lack of R&D personnel influence the firm's decision to source externally. Following the transaction costs literature, high levels of technological uncertainty disfavors external sourcing, while the technology management literature stresses that a lack of internal resources may drive the firm towards external sourcing.

The literature on complementarity between internal innovative capacity and external sourcing stresses different mechanisms through which this complementary relationship holds. The variable OPEN measures how important publicly available external information is to the innovative activities of the firm. This serves to control for the openness to and awareness of external know-how arising from the screening or scanning potential from internal resources. [6] The presence of a permanent R&D activity, measured as a dummy, captures whether own R&D substitutes for external technology or whether it functions as general "absorptive capacity", which complements externally sourced technology. *BasicRD* measures the importance for the innovation process of information from research institutes and universities relative to the importance of suppliers and customers as an information source. We use this variable to proxy for the "basicness" of R&D performed by the firm. A more basic type of innovation suggests less proprietary know-how in the initial phases of the technology life cycle. However, firms capable of assimilating a lot of information from universities or research institutes, probably possess higher absorptive capacity.

An important factor affecting the relative importance of different innovation activities of a firm, identified in the theoretical literature and so far ignored in the most empirical studies, is the appropriation regime. The survey assessed how effective the sample firms could appropriate the rents from their innovations. Different appropriation mechanisms could be identified: legal (patents and trade marks), and, strategic (complexity, secrecy or lead time). Firms that are more effective at appropriating the benefits from innovation will have larger payoffs from their external sourcing strategies. It remains to be seen whether this holds for all technology buying activities or whether different appropriation mechanisms affect different technology acquisition decisions, a question hitherto unexplored in the

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number between 0 and 1 for comparability. For a summary of the questions and categories we selected, see infra.

literature. For this we need to make a distinction between the demand and the supply of technology in the technology market. Firm- specific measures of legal and strategic appropriation affect the demand for technology to be acquired externally, while industry measures of legal and strategic appropriation affect the supply of technology to be acquired externally. One could hypothesize that if legal protection of innovations at the industry level is tight, firms that acquire technology externally are more likely to be able to obtain technology in disembodied form in these arms-length transactions. However, given tight legal protection, the only way to access technology externally, when not offered on the market, might be through indirect means such as reverse engineering, take-overs or hiring away personnel. If innovations are easily protected through strategic measures such as secrecy, lead time, or complexity of the product or process, firms are more likely to find technology tied to complementary assets and, therefore, when acquiring technology this is more likely to happen in embodied form. Nevertheless, the fact that strategic protection is effective at the industry level could reduce the opportunity to find technology externally and hence affects the acquisitive behavior of the firm. On the demand side, strong legal protection at the firm-level could encourage the firm to develop the technology internally rather than look for it on the external technology market. Strong strategic protection would allow the firm to appropriate the benefits of the integration of the externally acquired technology.

Finally, we include market concentration (measured by the C4 concentration measure) and the sectoral R&D intensity level. The concentration ratio captures the small numbers bargaining hazards as well as the fact that tacit agreements to not aggressively seek out new technologies which would intensify competition in the industry, are easier to enforce between a small number of competitors. The sectoral R&D intensity level captures technological opportunities present within the industry.

Insert Table 3 about here

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[6] Alternatively, to the extent OPEN may be associated with the availability of generally available external know-how that can be accessed as unvoluntary spillovers, it may be capturing complementarity between a "buy" and "take" option.

4.2 The econometric results

We analyse the firm and industry variables determining the decision to buy technology in general and per mode, using a probit model where the dependent variable is 1 when the firm claims to buy technology. The results of the estimation are presented in Table 4. The disembodied and embodied results allow us to summarize and compare the results from the individual modes per category. Reported as well are the results for the individual modes, licensing, R&D contracting, take-overs and hiring away skilled personnel [7]. The reported coefficients are the estimated partial derivatives of probabilities with respect to the vector of characteristics. They are computed at the means of the independent variables. The coefficient tells us how much the probability that the firm buys increases with an increase in that independent variable, holding the other independent variables constant. The high Chi-squared of the various models indicates the high joint explanatory power of the independent variables in all regressions.

Insert Table 4 about here

Larger firms are significantly more likely to acquire technology, both in embodied and disembodied form. Size is especially important when combining different acquisition modes, probably explaining why the size variable looses significance when considering most individual modes. After controlling for firm size, there remains a positive and strongly significant effect for openness to external information on the decision to acquire technology, both embodied and disembodied. This confirms the importance of a scanning capacity in external sourcing. Besides the scanning of external information, there is a positive effect for our measures of absorptive capacity. Permanent own internal R&D capacity and BasicRD significantly affect the decision to acquire disembodied technology.[8] Further disaggregation of this result over the two disembodied modes, licensing and R&D contracting, reveals that

[7] To save space, buying consulting services is not reported separately. These results are in line with those of licensing and R&D contracting, but lack significance because of the scarce number of observations.

[8] Other measures for own R&D capacity, besides a dummy for permanent R&D activities, such as importance of internal information to the innovation process, the R&D intensity, ... produced less significant results.

in-house development of technology in particular enhances the ability of the firm to realize benefits from R&D contracting. The relative importance of information from university and research institutes affects both licensing and R&D contracting, but is stronger for the latter.

In line with transaction cost theory, the perceived risks of innovation seem to discourage technology acquisition of the firm. Contrary to expectations, this is least likely to hold for R&D contracting. Lack of financial resources seems to push firms more in the direction of technology acquisition. This is most significant for embodied acquisition: take-overs and hiring away skilled personnel. Capital market imperfections arising from information asymmetries might be less impeding to find external funding for embodied acquisition than for internal development or disembodied acquisition of technology. A lack of qualified innovation personnel also drives the firm to acquire technology externally. Not surprisingly, the most significant external mode chosen in this case is R&D contracting.

An important determinant of the decision to buy technology, and whether this acquisition is in embodied or disembodied form, is the type of protection that is effective. If legal protection is effective for the firm (PROTlegal), firms are less likely to acquire technology externally. As expected, there is a significant negative effect of legal protection on the probability of embodied acquisition. But for licensing, a more effective legal protection is a significant catalyst at the firm level. At the industry level, we find that when legal protection is tight, more firms offer technology on the technology market. This is especially true for licensing. When the firm is better in protecting the rents from innovation through secrecy, lead time or complexity (PROTstrat), it is significantly more likely to acquire technology externally. Firms acquiring technology try to appropriate any rents through embodying the technology within complementary, but harder to replicate assets. If these firms tend to realize more benefits from external sourcing, it would explain the positive coefficient of strategic protection. The results indicate that this positive effect is only significant in the embodied acquisition modes. In addition, there is a negative industry effect, which suggests that the efficiency of the firm in protecting rents should be assessed relative to the industry level. Within industries with strong strategic protection less technology might be offered on the external technology market.

In general, industry characteristics add little explanatory power, after controlling for firm characteristics. Industry concentration shows up significant for the embodied acquisition of technology. The significant negative coefficient for concentration in hiring away skilled personnel, confirms the problems of small numbers bargaining and tacit agreements in markets for professionals. The R&D intensity at the industry level stimulates external acquisition, in particular in disembodied form.

To check the robustness of the results, we also performed a split regression by firm size, distinguishing small (ie <50 employees) from large firms. As already noted supra, for the small firms the results are mainly driven by the embodied choice, since they are less active in disembodied acquisition. While the openness variable is significantly positive both for small and large firms, the results for the BasicR&D and the PermRD variables are different. For large firms the coefficients are positive, suggesting complementarity between make and buy, be it that they are only significant for the disembodied buying. For small firms the coefficients are negative, indicating that at smaller scale of operations, the substitute relationship between make and buy is more prominent. The results on the protection variables are similar for the large and the small firms, but they are are more significant for the large firms, especially the strategic protection at the firm level. Also the obstacle-variables are only significant for the large firms.

5. Conclusions

While there is ample theoretical and empirical research on firm and industry determinants of internal R&D, the literature deals less with the choice between different innovation activities, in particular external technology acquisition. Using data from the Community Innovation Survey on Belgian manufacturing firms, we try to identify firm and industry characteristics that are most conductive to external technology sourcing. Our results indicate that the capability to scan the external environment for new technology is important in understanding the decision of the firm to buy technology. The capability of the firm to integrate new external knowledge into its innovation process, however, is only important for the disembodied technology acquisition, and more specifically for the R&D contracting. Appropriability through legal mechanisms positively affects disembodied technology acquisition, in particular licensing. Strategic protection, on the contrary, strongly determines the embodied technology acquisition mode. Other variables of interest are risk, costs and lack of innovation personnel. Higher riskiness of the innovation process reduces the likelihood that firms are able to agree on the transfer of disembodied technology and the lack of innovation personnel increases the likelihood of buying technology in the form of R&D contracting. High costs for developing technology drive firms to buy existing embodied technology.

Given the lack of previous empirical work on this topic, the first results generated by this paper provide some interesting suggestions for further theoretical work which distinguishes between different acquisition modes. At the same time, more empirical work needs to be done to check robustness of the results. The EUROSTAT/CIS data proves to be a rich set of information, allowing to replicate this exercise on other European countries. However, the qualitative nature of most of the information limits the analysis, in terms of quantifying internal and external sourcing strategies.

Most companies, and especially the larger companies, seem to combine various external acquisition strategies. In particular, different embodied (licensing and R&D contracting) and different disembodied modes (take-overs and hiring away personnel) are typically combined. An important issue for further research is hence to study the complementarity among "technology buy" strategies. When does the use of one external sourcing mode increase the efficiency of using other external modes within the innovation process of the firm? Checking whether the complementarity between the modes is driven by more than a common set of firm and industry characteristics, requires a specific analysis, beyond the scope of the current paper. Also the complementarity with other innovative strategies, such as R&D Cooperation and Technology Sell, await further exploration.

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Table 1: Technology Acquisition by Mode: Total Sample

Buy	331 [67%]	Disembodied	256 (77.3%)	Licensing 143 (43.2%)
				R&D Outsourcing 154 (46.5%)
				R&D Consulting 108 (32.6%)
		Embodied	218 (65.8%)	(Educational) Acquisitions 77 (23.3%)
				Hiring Personnel 194 (58.6%)
				Purchase of Equipment 276 [56%]
				Other forms of acquisition 168 [34%]

In round brackets are the numbers as % of number of buying companies; in square brackets are % of number of innovative companies.

Table 2: Technology Acquisition by Mode: Subsample of small companies (<50 employees)

Buy	75 [50%]	Disembodied	Licensing 23 (31%)
			R&D Outsourcing 19 (25%)
			R&D Consulting 12 (16%)
		Embodied	(Educational) Acquisitions 18 (24%)
			Hiring Personnel 50 (66%)
			Purchase of Equipment 73 [48%]
			Other forms of acquisition 45 [30%]

Inbetween round brackets are the numbers as % of number of buying companies; inbetween square brackets are % of number of innovative companies.

Table 3: Explanatory variables

SIZE	Firm Sales in 10^8 BEF.
PROTLEG	Aggregate measure of importance of patents, registration of brands, copyright as protection measure of innovation.
PROTSTRAT	Aggregate measure of importance of secrecy, complexity and/or lead time as a protection measure of innovation.
PERMRD	Dummy with a value of 1 if the firm is permanently active in R&D
OPEN	Measure of importance of publicly available information to the innovative activities of the firm
BASICRD	Measure of importance for the innovation process of information from research institutes and universities relative to the importance of suppliers and customers as an information source.
OBSTRISK	Measure of importance of high risks as an obstacle to innovation
OBSTCOST	Measure of importance of no suitable financing available as an obstacle to innovation.
OBSTPERS	Measure of importance of lack of R&D personnel as an obstacle to innovation.
INDPROTSTRAT	Importance of strategic protection at industry level.
INDPROTLEG	Importance of legal protection at industry level.
C4	Concentration ratio of the industry.
SECTRDINT	R&D to sales ratio of the industry

Table 4 Results of Probit Regressions for Cooperation

	(1) BUY	(2) DEMB	(3) EMB	(4) LICEN SING	(5) R&D-CONTR ACTING	(6) TAKE-OVERS	(7) HIRING AWAY SKILLED PERS
SIZE	0.061*** (0.031)	0.106** (0.048)	0.03*** (0.01)	0.021 (0.016)	0.019 (0.015)	-0.001 (0.007)	0.030*** (0.010)
PROTstrat	0.186** (.091)	0.029 (0.103)	0.343*** (0.099)	0.0004 (0.092)	0.096 (0.09)	0.113* (0.60)	0.348*** (0.099)
PROTleg	-0.025 (0.16)	0.241 (0.179	-0.379** (0.167)	0.266* (0.146)	0.120 (0.155)	-0.085 (0.108)	-0.265* (0.164)
PermRD	0.045 (0.051)	0.094* (0.058)	-0.069 (0.057)	-0.081 (0.055)	0.139*** (0.049)	-0.034 (0.042)	-0.042 (0.058)
OPEN	0.048*** (0.010)	0.046*** (0.012)	0.027*** (0.011)	0.0313*** (0.0102	0.0267** (0.0024)	0.0203** (0.008)	0.014 (0.011)
BASICRD	0.069 (0.104)	0.236** (0.115)	0.037 (0.12)	0.168* (0.105)	0.273** (0.106)	0.078 (0.077)	0.091 (0.112)
OBSTRISK	-0.221** (0.01)	-0.236** (0.109)	-0.057 (0.106)	-0.011 (0.097)	0.007 (0.099)	-0.120* (0.070)	-0.019 (0.103)
OBSTCOST	0.052** (0.026)	0.002 (0.03)	0.073*** (0.027)	-0.019 (0.024)	0.003 (0.025)	0.049*** (0.018)	0.049* (0.026)
OBSTPERS	0.058** (0.027)	0.064** (0.03)	0.018 (0.03)	0.028 (0.026)	0.074*** (0.028)	0.013 (0.020)	0.023 (0.030
INDPROTSTRAT	-0.569 (0.484)	-0.451 (0.537)	-1.083** (0.523)	-0.720 (0.473)	-0.180 (0.497)	-0.650* (0.370)	-1.106** (0.508)
INDPROTLEG	1.016 (.988)	0.349 (1.092)	2.465** (1.040)	2.323** (0.946)	0.531 (0.992)	1.459* (0.758)	2.059** (1.015)
C4	-0.234 (0.195)	0.150 (0.216)	-0.400* (0.217)	-0.015 (0.189)	0.302 (0.196)	-0.148 (0.159)	-0.347* (0.212)
SECTRDINT	1.105 (0.736)	1.355* (0.765)	-0.197 (0.789)	1.726*** (0.653)	0.353 (0.687)	-1.096 (0.753)	0.407 (0.759)
	$\chi^2 = 63.72^{***}$ LL=-261.96	$\chi^2 = 66.37^{***}$ LL=-286.88	$\chi^2 = 42.93^{***}$ LL=-305.99	$\chi^2 = 53.98^{***}$ LL=-254.28	$\chi^2 = 69.26^{***}$ LL=-256.59	$\chi^2 = 28.33^{***}$ LL=-194.16	$\chi^2 = 37.94^{***}$ LL=-302.48

*** significant at 1%, ** significant at 5%, * significant at 10%, standard errors between brackets.